Source and Path Characteristics of Dike Intrusion and Surface Faulting Earthquakes

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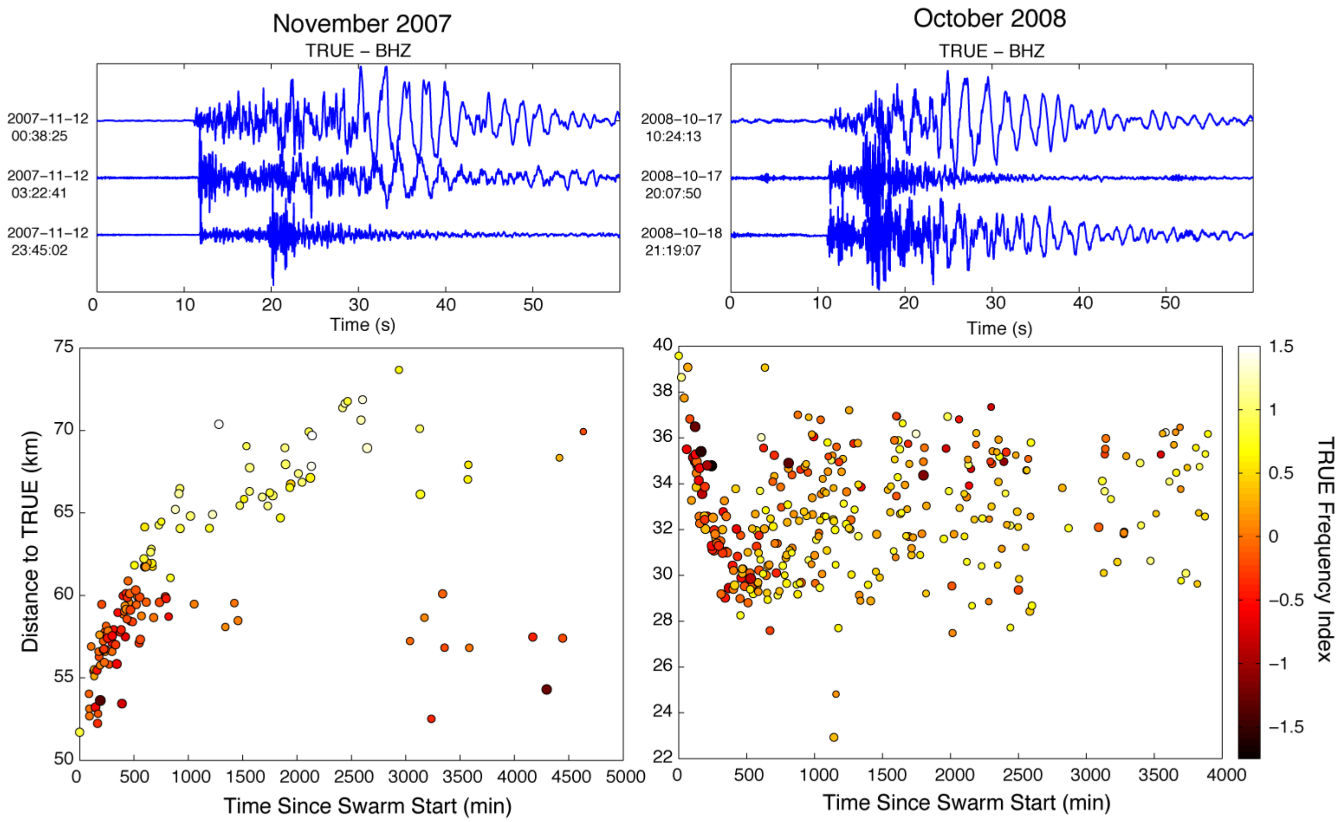

Volcanoes pose a risk for many local and regional populations in the US and throughout the world. A thorough understanding of magmatic processes and storage systems is necessary to better forecast volcanic hazards. Volcano and dike deformation, and associated magma system processes, is often measured through geodetic studies, but these methods only provide limited details about the geometry and evolution of magma intrusions. This project aims to use earthquakes to provide insight into diking processes that cannot be determined from deformation studies alone, ultimately leading to improved understanding and forecasting of volcanic hazards.

We analyze earthquake swarms from two large volume dike intrusions sourced from a mid-crustal magma chamber in a segment of the East African Rift in Afar, Ethiopia. Although earthquakes in the two swarms were M_L < 5, the dike intrusions caused surface fault displacements > 1 m across narrow swaths of the rift, demonstrating the hazards of dike-induced faulting. Many of the earthquakes in both swarms have high amplitude Rayleigh waves as well as enhanced low-frequency content in the P-waves that may be caused by one or a combination of fluid interactions, slow rupture, or shallow surface ruptures. Our aim is to evaluate these differences to discriminate between dike propagation earthquakes and shallow surface ruptures above the dike intrusion zone. The relative frequency content is characterized by the frequency index (FI), the log of a ratio of characteristic high- to low-frequency bands. More negative FI indicates comparatively more low frequency content. Most of the low FI earthquakes tend to occur in the first several hours of the dike intrusion sequence with a few low FI earthquakes occurring after propagation. There is some magnitude dependence on FI, as expected. We find no clear source depth dependence on FI, given standard errors and the small depth range of < 9 km subsurface.

Other parameters, such as corner frequency and stress drop, provide further insight into earthquake processes and their relation to dike intrusion processes. For closely located, similar earthquakes, an empirical Green's Function (EGF) method is commonly used to isolate the source processes. The EGF method deconvolves a small earthquake, treated as an impulse response, from a larger earthquake to effectively remove path effects. The resulting source-time functions of the larger earthquakes or spectral ratios of the earthquake pairs are used to determine the corner frequency, rupture time, stress drop, and scaling relations of the earthquakes. FI is additionally useful for identifying ideal earthquake pairs for EGF analysis. Initial EGF results suggests the swarm earthquakes have corner frequencies within the typical range, indicating normal, tectonic source processes.